present invention, the outer cylindrical surface 140b of the center shaft 140 is smaller in surface roughness Ra defined in Japanese Industrial Standard (JIS) B 0601 than 0.1 μ m, and the outer cylindrical surface 140b of the center shaft 140 is larger in Vickers hardness Hv defined in JIS Z 2244 than 650.

The sealing lip 154c of the annular resilient member 154 may be held in contact with the outer cylindrical surface 140b of the center shaft 140 with a vacuum grease constituted by a lubricant containing fluorine. The first sealing unit 150 may include a plurality of sealing rings 153 each having a sealing lip 154c coated with the vacuum grease. The first sealing unit 150 may also include a plurality of sealing rings 153 each having a sealing lip 154c to have the sealing lips 154c collectively form an annular groove filled with the vacuum grease. The first sealing unit 150 may also include a plurality of sealing rings 153 each having a sealing lip 154c and a subsidiary sealing lip held in contact with the outer cylindrical surface 140b of the center shaft 140 to have the sealing lip 154c and the subsidiary sealing lip collectively form an annular groove filled with the vacuum grease.

The shaft sealing apparatus 100 further comprises a first bearing 159 intervening between the center shaft 140 and the sleeve shaft 130 to have the center shaft 140 movably supported by the sleeve shaft 130 through the first bearing 159. The first bearing 159 is located between the sealing ring 153 of the first sealing unit 150 and the second axial end of the center shaft 140 in axially spaced-apart relationship with the sealing ring 153 of the first sealing unit 150.

The shaft sealing apparatus 100 further comprises first driving means constituted by an electric motor, not shown. The electric motor is operatively connected with the second axial end of the center shaft 140 to rotate the center shaft 140 around its own axis. While the driving means has been described in the above as being constituted by an electric motor operatively connected with the second axial end of the center shaft 140, the electric motor may be replaced by a reduction gear unit and an electric motor operatively connected with the second axial end of the center shaft 140 through the reduction gear unit.

The shaft sealing apparatus 100 further comprises a second sealing unit 160 received in the opening 110b of the vacuum casing 110 and fixedly supported by the base portion 110a of the vacuum casing 110. The second sealing unit 160 includes a retaining member 161 in the form of an annular ring shape and fixedly connected with the base portion 110a of the vacuum casing 110 by bolts 162, and a plurality of sealing rings 163 securely retained by the retaining member 161 of the second sealing unit 160 to be held in axial alignment with each other. Each of the sealing rings 163 of the second sealing unit 160 is in the form of an annular ring shape and intervenes

between the retaining member 151 of the first sealing unit 150 and the retaining member 161 of the second sealing unit 160 to hermetically seal the gap between the retaining member 151 of the first sealing unit 150 and the retaining member 161 of the second sealing unit 160. The sealing rings 163 of the second sealing unit 160 are held in contact with each other.

The retaining member 161 of the second sealing unit 160 has a first axial end 161a extending in the vacuum chamber 111 of the vacuum casing 110, a second axial end 161b extending in the atmosphere 112, and an inner cylindrical surface 161c larger in diameter than the outer cylindrical surface 151d of the first sealing unit 150. The inner cylindrical surface 161c of the retaining member 161 is formed with an annular ledge 161e connected with the second axial end 161b of the retaining member 161.

Each of the sealing ring 163 of the second sealing unit 160 includes an annular resilient member 164 formed with an annular groove 164a, and an annular spring member 165 received in the annular groove 164a of the annular resilient member 164 and retained by the annular resilient member 164 as shown in FIG. 2. The annular resilient member 164 of the sealing ring 163 has a peripheral portion 164b securely retained by the annular ledge 161e of the retaining member 161, and a sealing lip 164c integrally formed with the peripheral portion 164b of the annular resilient member 164 and radially inwardly extending from the peripheral portion 164b of the annular resilient member 164 to be held in contact with the outer cylindrical surface 151d of the first sealing unit 150. The sealing lip 164c of the annular resilient member 164 is made of a synthetic resin constituted by an ultra high molecular weight compound.

The annular resilient member 164 of the sealing ring 163 may have a reinforcing portion 164d covered by a rubber and intervening between the peripheral portion 164b of the annular resilient member 164 and the sealing lip 164c of the annular resilient member 164 to have the annular resilient member 164 reinforced with the reinforcing portion 164d. The reinforcing portion 164d of the annular resilient member 164 is made of a metal plate in the form of an annular ring shape and is of an L-shaped cross-section taken on the plane perpendicular to the center axis passing therethrough.

The annular spring member 165 of the sealing ring 163 is operative to impart a force to the sealing lip 164c of the annular resilient member 164 to ensure that the sealing lip 164c of the annular resilient member 164 is held in tight contact with the outer cylindrical surface 151d of the first sealing unit 150. The annular spring member 165 of the sealing ring 163 is made of a metal wire in the form of a helical

shape and is of a circular cross-section taken on the plane perpendicular to the center axis passing therethrough. The annular spring member 165 thus constructed is generally called "garter spring".

In the first embodiment of the shaft sealing apparatus according to the present invention, the outer cylindrical surface 151d of the first sealing unit 150 is smaller in surface roughness Ra than 0.1 μm and larger in Vickers hardness Hv than 650.

The sealing lip 164c of the annular resilient member 164 may be held in contact with the outer cylindrical surface 151d of the first sealing unit 150 with a vacuum grease constituted by a lubricant containing fluorine. The second sealing unit 160 may include a plurality of sealing rings 163 each having a sealing lip 164c coated with the vacuum grease. The second sealing unit 160 may also include a plurality of sealing rings 163 each having a sealing lip 164c to have the sealing lips 164c collectively form an annular groove filled with the vacuum grease. The second sealing unit 160 may also include a plurality of sealing rings 163 each having a sealing lip 164c and a subsidiary sealing lip held in contact with the outer cylindrical surface 151d of the first sealing unit 150 to have the sealing lip 164c and the subsidiary sealing lip collectively form an annular groove filled with the vacuum grease.

The shaft sealing apparatus 100 further comprises a second bearing 169 intervening between the sleeve shaft 130 and the shaft housing 120 to have the sleeve shaft 130 movably supported by the shaft housing 120 through the second bearing 169. The second bearing 169 is located between the sealing ring 163 of the second sealing unit 160 and the second axial end of the sleeve shaft 130 in axially spaced-apart relationship with the sealing ring 163 of the second sealing unit 160.

The shaft sealing apparatus 100 further comprises second driving means constituted by an electric motor, not shown. The electric motor is operatively connected with the second axial end of the sleeve shaft 130 to rotate the sleeve shaft 130 around its own axis. While the driving means has been described in the above as being constituted by an electric motor operatively connected with the second axial end of the sleeve shaft 130, the electric motor may be replaced by a reduction gear unit and an electric motor operatively connected with the second axial end of the sleeve shaft 130 through the reduction gear unit.

The shaft sealing apparatus 100 further comprises a fixed member 180 in the form of a cylindrical hollow shape and provided on the first axial end 151a of the first sealing unit 150. The fixed member 180 is held in axial alignment with the sleeve shaft 130 and fixedly connected with the first axial end 151a of the first sealing unit